International Journal of Mechanical and Production
Engineering Research and Development (IJMPERD)
ISSN(P): 2249-6890; ISSN(E): 2249-8001
Vol. 9, Issue 1, Feb 2019, 291-296

Original Article

ADVANCED FABRICATED SETUP FOR DAY LONG PRODUCTION OF HOT WATER BY FRESNEL LENS

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ABSTRACT

This work has been aimed to collect the solar energy source from Fresnel lens and utilize it to produce hot water or steam. The setup consists of a large spot Fresnel lens which concentrates the sun's rays into a one-centimeter square spot onto a copper tube with the temperature reaching around 200 °C. This concentrated heat is focussed on copper tube absorber to heat the water, the hot water then can be used for a variety of purposes, like sterilize utensils or different equipment in hospitals, restaurants etc and for cooking purposes. The setup also consists of a solar tracking system consisting of light resistive sensors and a microcontroller with a relay setup that controls the movement of the frame. The experiment has been conducted from morning 9 am to 5 pm, with ever-changing hours the sun was automatically tracked with the help of a solar tracking system. From the experimental results, it has been observed that the maximum temperature of water obtained was 81 °C at 13:00 hours.

KEYWORDS: Fresnel Lens, Conventional Lens, Renewable Sources, Microcontroller & Light Resistive Sensors

Received: Nov 21, 2018; **Accepted:** Dec 11, 2018; **Published:** Jan 08, 2019; **Paper Id.:** IJMPERDFEB201928

INTRODUCTION

In the present scenario, the major problem is need for electricity. Due to environmental issues and limited fossil fuel resources, more and more attention is being given to renewable energy sources. Recent studies show that public is using less energy overall and making more use of renewable energy resources in developed countries like the United States of America, United Arab Emirates and Australia. Even in India consumers are swayed towards Renewable Energy due to the power crisis. Conventional energy sources will be depleted in due course of time. Hence future energy demands can be met only by non-conventional energy sources. Coming to solar we can obtain energy from both light and heat. However we cannot obtain energy for 24 hours by just using photovoltaic cells. Even though we use battery backup it has to be charged to provide uninterrupted power supply. But solar heat can be stored and used to generate electricity for 24 hours. This is the concept of Concentrated Solar Power. In this work mirror or Fresnel lens has been used to focus the solar heat into single area near heat engines and steam engines or Stirling engine. The Solar collectors normally used are power tower, dish Stirling, parabolic trough and Fresnel reflectors. These methods are adopted and implemented in various parts of the world and they produce energy in terms of mega watts (IulianaSorgia et al 2012).

Literature Review - Solar Energy Systems Using Fresnel Lenses

Using of a Fresnel lens as a solar concentrator has been in practice since from 1960, because of their advantages like high optical efficiency low weight and cost-effectiveness (Leutz R, Suzuki A et al 2000). However major studies conducted on concentrated solar energy applications using Fresnel lens for multiple applications can

be grouped under two main fields namely, imaging Fresnel lens systems and non-imaging systems. Figure 1, depicts the differences between the conventional lens and a Fresnel lens, different lenses designed for imaging devices rather than for the collection of solar rays. Applications like the monocrystalline photovoltaic generation of electricity are often equipped with imaging.

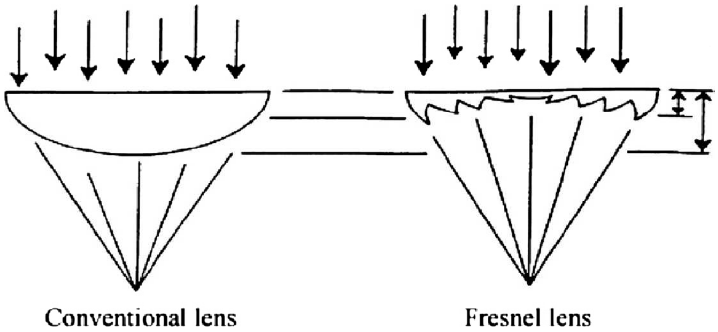

Figure 1: Conventional Lens and Fresnel Lens (Sierra C et al 2005)

The imaging Fresnel lens refracts lights from an object an image on the focal plane.

The Fresnel lens and accurate tracking have to be employed to keep the focus of the lens in place on the receiver.

Joshua Folaranmi et al. (J. Folaranmi 2009) presented an experimental investigation on the design, construction, and testing of a parabolic dish solar steam generator. The heat from the sun is concentrated on a black absorber located at the focus point of the reflector in which water is heated to a very high temperature to form steam and the sun tracking system unit is used for manual tilting of the lever at the base of the parabolic dish to capture solar energy. The frame and slotted lever mechanism used for tilting the parabolic dish reflector to different angles so that the sun is always directed to the collector at different period of the day. On the average sunny and cloud-free days, the test results gave high temperature above 200°C.

The parabolic trough solar collector system has been successfully used for heat generation process in many industrial applications and also it provides the useful information for technical evaluation and economic feasibility of similar system in many countries (Steve Ruby et al 2010).

These concentrating solar power systems provide the hot water more than 232 ^{o}C (450^{o}F). The process steam in the plant is used for cooking heating edible oil for frying and heating baking equipments.

Observations from Literature Review

- As compared to a parabolic concentrator, the Fresnel lens requires a smaller-field of view.
- Compared to a parabolic concentrator, a Fresnel lens produces a larger amount of heat.
- A Fresnel lens requires less material than conventional lenses, and hence it is lighter and portable.
- Processed steam in the plant is used for power generation, cooking and the Steam is also converted into hot water for cleaning and sterilization processes.

The main objective of the study is to produce hot water or steam using a renewable source of energy that is the sun in order to heat up water there by reducing the amount of pollution to zero as compared to when we use non-renewable sources of energy like fossil fuels, wood, coal etc. To utilize the energy of the sun by concentrating the sun's rays onto a

small point this can reach temperatures of up to 300 degrees Celsius and to produce hot water with lowercost as compared to conventional source. To utilize solar tracking system to control the movement of the Fresnel lens setup according to sun movement so that maximum solar energy can be harvested to get full estutilization of solar energy.

METHODOLOGY

The main aim of the work is to heat up water using renewable sources of energy like the sun using a Fresnel lens which helps to concentrate the sunlight into a small spot. The tracking of the Fresnel lens was done using a solar tracking system and tilt angle of the Fresnel lens is about 23^0 as per the study. The experiment carried out helps to determine the time required to heat the inlet water and the maximum temperature of the water.

The Fresnel lens is mounted north to south at an inclination of 23^0 and tracking of sun from east to west can be done using solar tracking system which consists of three light dependent resistor sensors which track the movement of the sun and in turn move the setup consisting of the Fresnel lens with the movement of the sun that is from east to west. Since sunset, the setup will remain in the west position until sunrise when the east sensor gets activated by the sun’s rays and the setup will move towards the east. The setup then moves towards the middle sensor at midday and finally towards the west at sunset. Similarly, the whole cycle is repeated. During experimentation absorber temperature, feed temperature and the outlet temperature of water are measured by using a laboratory thermometer.

Experimental Setup

The test setup as depicted in figure 2, consists of an absorber, Fresnel lens, frame and solar tracking system ; the absorber material was made of copper. The absorber is made in the shape of a tube which is 130 mm in length and 15 mm in diameter. Two non-return valves made of steel are brazed on to the ends of the copper tube with the help of brass nuts. These valves are used to control the flow of water through the copper pipe. The aluminium plate with the copper tube is then mounted on a steel support bar which if fixed to a shaft that helps to move the copper tube in the direction of the sun using the solar tracking system. The water is fed to the absorber through inlet from the feed tank and when absorber receives the sunlight, water inside the absorber gets heated up. The hot water then flows through the outlet into the outlet water collection tank.

Figure 2: Experimental Setup

The solar concentrating Fresnel lens used for the experimentation was made of acrylic material. The area of the Fresnel lens was 200mm×300 mm and it has a focal length 260mm. The effective area was 300 mm × 200 mm when mounted on lens frame. The lens frame is made of mild steel. The Fresnel lens has a transmission efficiency of 0.85 to 0.9 as per literature (ObaidYounas et al 2013).

A mild steel frame was made for the Fresnel lens which can be tilted from side to side using a bush and bolt type arrangement, the setup can also be moved up and down in order to set the focal point. This is done using grooves provided in the aluminium frame used to support the copper absorber. The entire Fresnel lens and copper absorber setup can be moved from east to west along with the sun using the sun tracking system. The frame for the Fresnel lens which is 540mm x 200 mm is mounted on the aluminium base is supported on a mild steel bar of 330 mm height which is fixed to a mild steel shaft of 10 mm diameter and 640 mm length. A motor is coupled to the shaft using four gears of teeth 22, 68, 22, 68 respectively in order to reduce the rpm of the motor from 55 to around 13 rpm. The motor and shaft are mounted on the bottom part of the frame which is made of mild steel square hollow pipe. Two ball bearings of 15 mm inner diameter and 40 mm outer diameter is used to support the mild steel shaft. Finally, a water tank of 190mm x190mm x 190mm dimension is used to store the water.

The solar tracking system consists of 8051 base board with an AT 89 S52 microprocessor which controls the entire circuit; it can also be programmed to control the speed of the motor. A two channel relay is used to control movement of the Fresnel lens and absorber setup. Three light dependent resistor sensors are used namely east, middle and west sensor which tracks the location of the sun. Two comparators are used which switches the circuit on or send a signal to the microprocessor when any one of the sensors get activated due to the sunlight falling on it. The microprocessor controls the sequence so that the motor will run only when the sensors are triggered in a particular order that is east, middle and finally west sensor. When the sun sets the west sensor is triggered and the when the sunrises the next day the east sensor is triggered which moves the setup to the east and the whole process is repeated again. A 12 volts 2 amps wiper motor is used to which power is supplied using a 12 volts 7.5 amps battery, also a manual switch is used in order to move the lens setup in case the sensor fails.

RESULTS AND DISCUSSIONS

The experiment was conducted from morning 9 am to 5 pm and the results has been tabulated in table 1.

The main goal of the experiment was to generate hot water with low pressure steam. The readings has been recorded throughout the day and tabulated for each successive 30 minutes from 9.30 am to 4.30 pm as depicted in table 1.

Table 1: Inlet to Outlet Water Temperature Variation

Time IST	Feed Water Temp. in ^{0}C	Outlet Water Temp. in ^{0}C	Time IST	Feed Water Temp. in ^{0}C	Outlet Water Temp. in ^{0}C
9:30 am	25	45	1:30 pm	27	79
10 am	25	46	2 pm	27	79
10:30 am	26	48	2:30 pm	26	75
11 am	26	59	3 pm	26	75
11:30 am	26	59	3:30 pm	26	73
12 noon	27	62	4 pm	26	69
12:30pm	27	72	4:30 pm	26	61
1 pm	27	81			

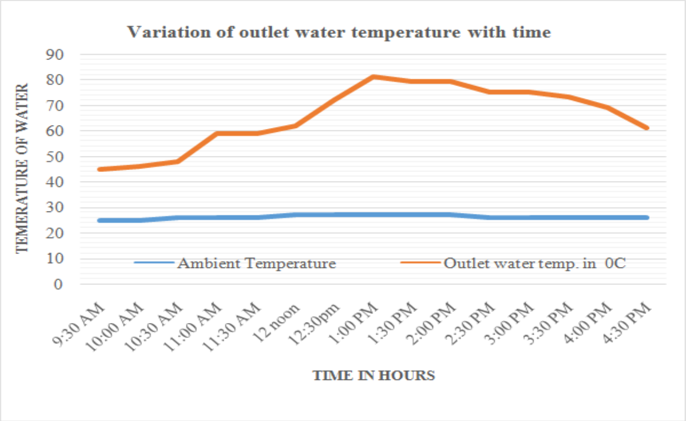

Figure 3: Variation of Outlet Water Temperature with Time Duration

The figure 3 depicts the variations in temperature of the inlet and outlet water. The graph was plotted for the best outcome results. It was noted that the maximum temperature obtained was 81 ^{o}C at 1:00 pm.

CONCLUSIONS

Based on the result and discussion carried out the following conclusions were drawn

- Maximum solar radiation were found to be 1320.44 watt/square meter and it was also noted that the radiation was found to be more intense from12:30 pm to 2:00 pm.
- The maximum surface temperature attained on the absorber made from copper tube was around 200 ^{o}C.
- The system showed a lot of fluctuation of the outlet water temperature with the increase in amount of cloud cover.
- It was possible to generate hot water but not steam as the size of the Fresnel lens used was small and hence the maximum absorber temperature obtained was only 200 ^{o}C. The time required to heat the water was around 35-40 minutes.
- The need for the construction of a Fresnel lens collector solar steam generator arose as an alternative to solve the thermal energy needs of the populace.
- This work also helpful in the production of high-temperature water for baking and cooking systems.

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